Advanced Tall Buildings Systems Integration

Thomas Fowler, Kevin Dong

Cal Poly State University, San Luis Obispo

Abstract

The 2020 Skyscraper Collaboratory was a partnership between Cal Poly, San Luis Obispo, California University's interdisciplinary design studio (architecture and structural engineering) and the design / structural engineering partners from Skidmore, Owings & Merrill's (SOM) San Francisco, California's Office, an internationally acclaimed firm that specializes in skyscrapers. The academic design studio was set up to mirror the advanced collaborative practice model of the partner firm, by balancing the nine teams (34 students total) with architecture and engineering students and co taught by faculty architect and structural engineer. No disciplinary hand offs were ever allowed during the iterative design and technical process.

The site for the project located in downtown San Francisco, California with a height of 800', and ½ million square feet of housing with the retail in the lower floors.

Sixty percent of the students in the studio were in the third year of the 5-year BARCH program and prior design experience was limited to the design of 1-2 story commercial buildings. The remaining students were 4th year structural engineers (with a handful of graduate students) focused on using this collaboration as their senior project.

Over a twenty-week period, six courses (2 design studios, and 4 technical courses) were synced up and coordinated with the partner firm's lectures, reviews and workshops conducted for design studio. The sequence of coordinated academic and technical content was: structural prototyping / designed physical model weight testing; 51 precedent dissections; structural system optimization, building energy modeling, performative envelopes, housing design/vertical communities and urban placemaking.

What started as an in person collaborative design studio was upended by the changes of the pandemic and the need to abandon all foundational hand-crafted large scaled physical model studies. The remote collaboration workflow strategies expertise that our partner firm was able to successfully share with design studio, was a key factor to the success of studio.

Keywords: Interdisciplinary Collaboration, Skyscraper Structural System, Steel Structure, Advanced Tall Buildings Systems Integration, and Cladding System

The Collaboratory

The Skyscraper

A unique building type for a design studio that required the balanced collaborative interdisciplinary architecture and structural engineering student teams to not only establish a clear story for design conceptualization, but to also follow through with the design development and integration of advanced building systems (i.e., high rise structural system / wall assembly / environmental systems). This provided an *opportunity to expand the exploration of the tectonic and social implications of this building type.*[1] The studio was set up to address head on, the high-rise building type *… as a crossroads between the global process of densification shaping contemporary urban development and the protocols and iconographies that define cultural specifics.*[2] The integrated design studio course reader provided a range of articles on high-rise building history/theory, programing, place making, and structural systems.

The Collaboratory Philosophy

The goal of the academy is to educate future design professionals, prepare individuals for a changing world, and provoke thoughtful designs which address environmental and performance criteria while exhibiting technical excellence. In order to do this, for such as large scaled project, the paper authors developed an interdisciplinary design studio which blurs the line between building structural systems and architecture using the philosophies embodied in Ove Arup's Key Speech, in which he describes the *melding of disciplines to create a holistic design*[3]; and studio-based learning outlined in Donald Schon's work, Educating the Reflective Practitioner (1987) in which he states: *Designing, both in its narrower architectural sense and in the broader sense in which all professional practice is design like, must be learned by doing.*[4]

The Collaboratory Components

The paper authors worked closely with industry partners, Leo Chow, Design Partner and Mark Sarkisian, Structures Partner @ Skidmore Owings and Merrill

(SOM) to plan the course a year in advance. Dealing with two very busy partners, a total of 6 required classes for 34 students in 2 different disciplines (architecture and architectural engineering) was a challenge.

The six (6) required courses that were knitted together into the Collaboratory included:

1.Third Year Building Design Studio with

Third Year Technical Systems Integration Courses:

2.Energy Modeling/Environmental Systems

3.Wall Assembly Systems

4.Building Structural Systems

5.Fourth Year Engineering Students Interdisciplinary Capstone Senior Project

6.Graduate Level Advanced Building Design Studio for several of the Engineering students

Five (5) components were developed to structure the Collaboratory, to instill the importance of a balanced architecture and structural engineering design team approach to project:

A. Building Systems Integration principles from the big ideas of the project (the story) and have these elements reflected in the developed building systems for the designed project (structure; environmental controls systems that relate to day lighting, cladding, shading and ventilation; building navigational systems that include egress, accessibility, site and urban placemaking).

B. Interdisciplinary teamwork approach to project and linkages to the deep research that is applied to the design work.

C. Clear project representation / documentation for telling the project story and accomplished on a daily basis along with reflective journals that were developed weekly by all students.

D. Programming and reiterative design development for critical development of project.

E. No disciplinary hand offs are allowed during the project's process, meaning that all contribute to all levels of design development of project.

Collaboratory Course Reader / Discussions

A course reader was developed with a range of articles on the skyscraper, covering topics that included history, structural systems along with discussions on urban placemaking. The course reader provided students with an understanding of the role of structure as form maker, the role of structural tectonics in the development of concepts and form making, exploration of urban place making and learning to work in a collaborative manner.

The Collaboratory Course Calendar

Calendar Details

Week 00:
- Pre-Course Readings [Univ]
- Collaborative Team Assignments [Univ]

Week 01:
Structural Prototyping / Weight Testing [Partner/Univ]
- Story-telling and weight testing of structural skeleton [Partner]
- Site Visit / Energy Modeling [Partner/Univ]

Week 02:
51 Precedent Dissections [Partner/Univ]
- 5 Categories: function, vertical communities, performative envelop, urban placemaking, and structural tectonics

Week 03:
- Skyscraper Program [Partner/Univ]
- Building Structural Systems [Partner/Univ]
- Lecture [Partner]: *Structural Skyscraper Dynamics*

Week 04:
- Project Review #1: Skyscraper Concepts [Partner/Univ.]

Week 05:
- Lecture [Partner]: *Service Cores*

Week 06:
- Project Review #2: Skyscraper Refinements [Partner/Univ.]

Week 07:
- Lecture [Partner]: *Structural Systems / Wind Engineering*

Week 08:
- Project Review #3: Skyscraper Refinements [Partner/Univ.]

Week 10:
- Project Review #4 (Midterm Review) [Partner/Univ.]

Weeks 11 & 12:
- COVID 19 Impacts / Pivots [From In person to all remote learning]
- Cancelled field trip to SOM's Chicago Office to test team designed wind tunnel models, due to the pandemic, plus university extended spring break for an additional week.

Week 13:
- Lecture [Partner]: *Skyscraper Wind Engineering, Part 2*
- Project Review #5 [Partner]: Wind Engineering Team Foam Models [Partner/Univ.]

Week 14:
- Project Review #6: Skyscraper Building Systems Integration Refinements [Partner/Univ.]

Week 15:
- Lecture [Partner]: *Performative Envelope*

Week 16:
- Lecture [Partner]: *Structural Optimization Lectures 1 & 2*

Week 17:
- Project Review #7: Skyscraper Integration Systems [Partner/Univ.]

Week 17-18:
- Pre-Final Skyscraper Integration Adjustments

Week19:
- Final Reviews [Partner/Univ.]

Week 20:
- Wrap Up Surveys, Evaluations, and Reflective Essays

Collaboratory Assignments

Weight Testing Models Assignment (Fig. 1):
The act of construction at its most fundamental level is one of lifting and supporting a mass above the ground. Whether this is for a sheltering roof, a raised platform offering a vista, or multiplying floor areas, the challenge for the architect/engineer is to accomplish this with the minimum expenditure of material and maximum artistry and functionality.[5]

Students worked individually to design a structure to support minimum, a standard American construction brick (3- 5/8" x 2-1/4" x 8"; 4.5 lbs.) 18 inches above the table or floor surface and must only use basswood material with glue only (no fasteners).

This task expanded beyond the functional to incorporate a design idea, tectonic requirements, and craft. The design idea not only emphasized the aesthetic, but also became the driver for how all decisions are made.

Three criteria used to assess the results of this exercise: 1. Concept - Is there an idea that goes beyond simply supporting the brick? 2. Aspect Ratio - Proportion is a significant consideration in the aesthetic evaluation of an object. 3. Weight - Weight supported ÷ weight of structure.

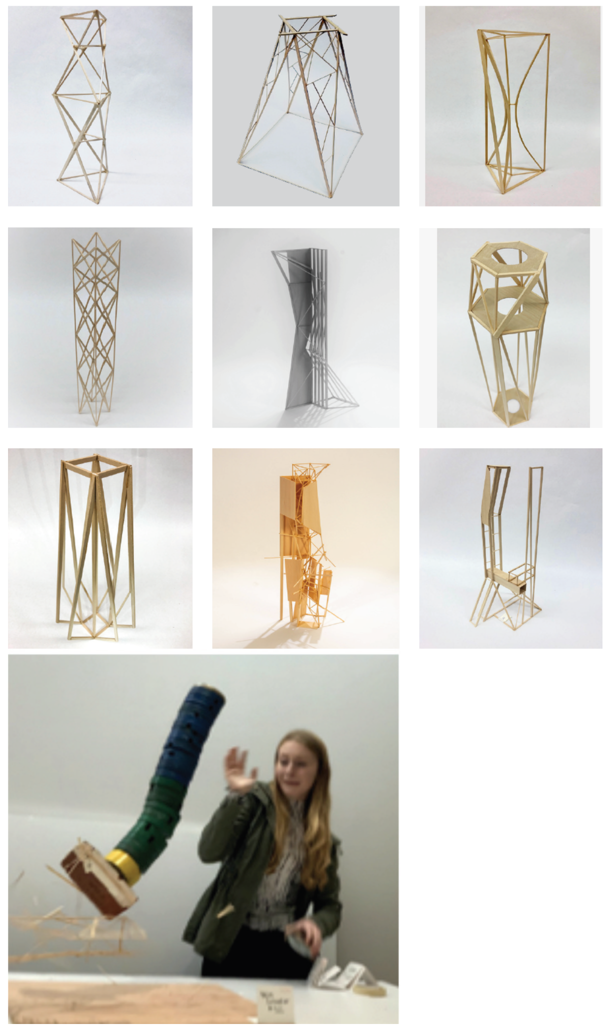

Fig.1 (above) Sampling of Individual weight tested physical models (pre-test views) and (below) model weight testing action shot.

Structural Prototyping Assignment (Figs. 1, 2).
As an outgrowth of the weight testing models assignment, each team developed a minimum of 3 iterative options of: digital and physical volumetric models of structural prototypes into evolving concepts for project.

Precedent Dissections Assignment (Fig. 3)
51 tall building precedent studies were divided equally across the nine teams in the following categories: function, vertical communities, performative envelope, urban placemaking, and structural tectonics.

Energy Modeling / Wall Assembly Assignments (Fig. 6)
Each team developed a technical understanding of material assemblies coupled with linkages to the story of project and sun shading and passive wind strategies.

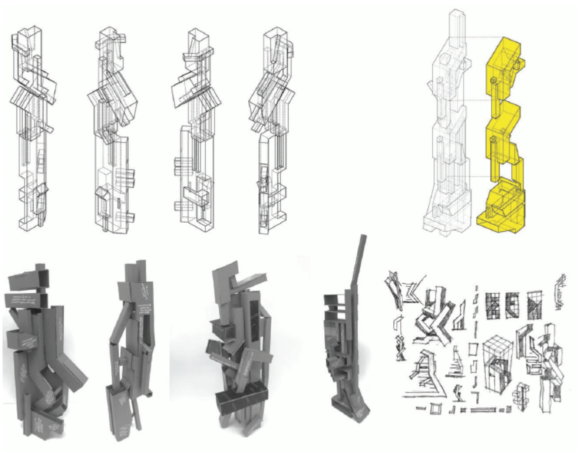

Fig. 2. Sample Team Project: 'Knotted Tubes' Structural Prototyping Assignment

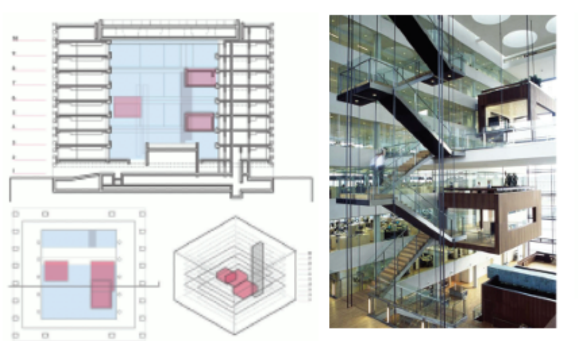

Fig 3. Sample Precedent Dissection Study: Vertical Community: Nykredit Headquarters - Schmidt Hammer Lassen

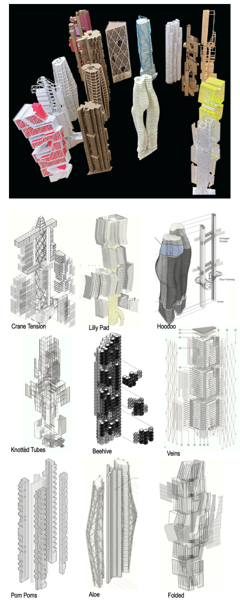

Fig. 4. (Top) Mid Review Physical Tower Models (Bottom) Exploded Tectonic Isometric Views of All Nine Team Designed Towers

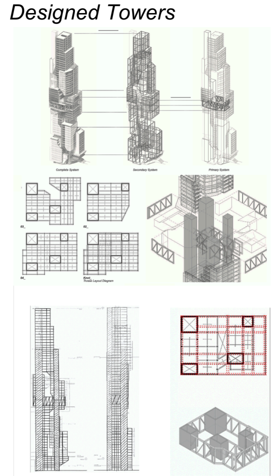

Fig. 5. Sample Team Project: 'Knotted Tubes' Building Structural Systems Design

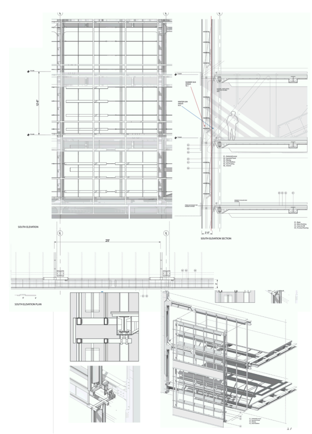

Fig. 6. Sample Team Project: 'Knotted Tubes' Cladding System Design

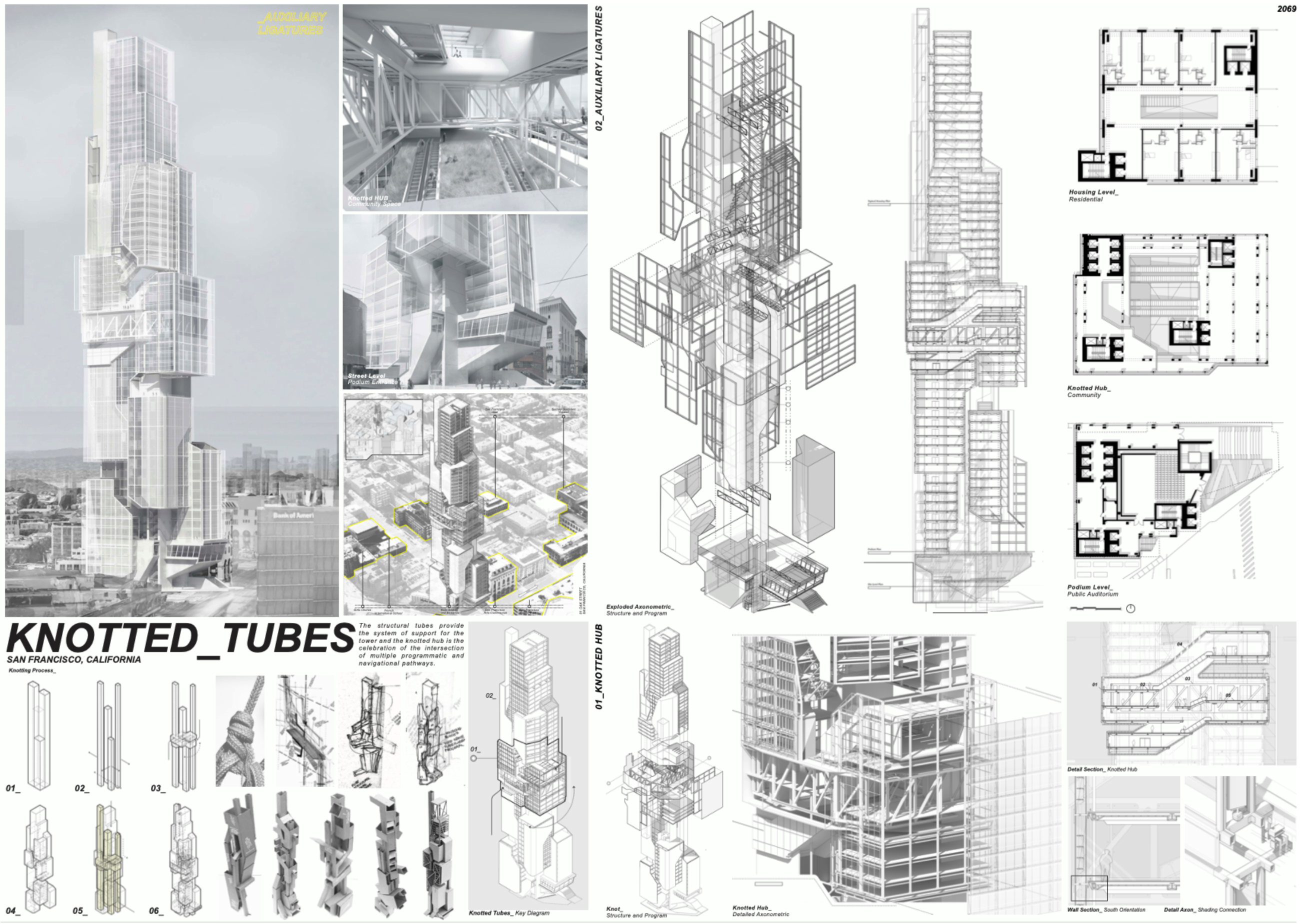

Fig. 7. Sample Team Project: 'Knotted Tubes' Final Poster

Collaboratory Comprehensive Tower Projects *(Figs 4, 5, 6, 7)*

The collaboratory had many moving parts, and at times was a bit overwhelming for students in collaborative teams to sort out the best workflow strategies in evolving the design of projects. The first 10 weeks of the course was to establish the clear commitments to tower's story from foundational structural prototyping studies and application of lessons learned from five categories of precedent dissection studies, along with application of knowledge from linked technology courses. Figure 4 shows all of nine of the collaborative team's physical model studies at the midpoint of the course (week #10), along with the digital tectonic models that show the exploded isometric structural integration diagrams. The second 10 weeks of the course, collaboratory teams worked with SOM, along with linked building structures course (taught by Dong) and cladding course (taught by Fowler with shared content with Dong, plus architecture lecture course to the entire third year student body talk by others), provided a framework for each of the teams to refine the design of tower project's building systems.

The "Knotted Tubes" project (Figs 5, 6, 7) provides a sample of the structural / cladding systems / energy modeling studies (and can also see the earlier foundational structural prototyping assignment, Fig. 2), that all teams developed over the 20-week period of course. Figure 7, "Knotted Tubes" project shows an example of the final comprehensive poster.

The concept behind the "Knotted Tubes" project was in the re-evaluation of the traditional bundled tubes skyscraper typology. Exploration in the separation of these tubes and their knotting or reconnection at a single junction became a focus of this project's design. The "Knot" expressed in the tectonics of project celebrates the dominate vertical community space in the tower.

Collaboratory Assessment Methods

There were four (4) categories used to evaluate the work and individual performance of team members. These assessment components were helpful to the instructor's in understanding what and how students were learning along with how the collective work of the team was going and what adjustments were needed to be made in the course to improve the workflow for the collaboratory.

Assessment Components

1. Studio and Periodic Disciplinary Assignment/Project Evaluation Rubric - for team and for individuals

2. Review Buddy Notes - prepared by each team for another team's review

3. Weekly & Collective Mid and Final Reflective Essays

4. Trust Battery Survey[6] - by each student and posted anonymously every 5 weeks for check-ins to see how each team is working and for instructors to assist, as needed, with helping to sort out conflicts

Lessons Learned

In spite of this collaboration having many moving parts along with a large cohort of students to manage at times, and of course the sudden surprise of needing to pivot and abandon all of the physical modeling that was replaced with remote only collaboration, the experience of mirroring in many ways academically in the classroom how SOM practices architecture, was action packed with beneficial lessons to both the students and us the co teaching instructors. There was a benefit in going remote for the second half of the project, since all teams had to hone their communication and representation skills in real time to make up for the inability to meet in person. The downsides of the remote environment, is that when there were team workflow / personality conflicts, the remote environment seemed to magnify these problems. We were, however, very fortunate to have had this opportunity to work with SOM at this particular time, due to their familiarity for using remote tools across a number of geographical time zones on a regular basis and therefore being able to share effective strategies for accomplishing interdisciplinary design with the same communication mediums that we were using (ZOOM, Google Slides and SLACK). This sharing of remote work flow strategies was helpful to the students (along with the instructors being quite surprised by how rudimentary these tools were but at the same time being so effective), and also was a relief to the instructors who at first had huge concerns for how his intense collaboration was going to continue effectively, since it was heavily analog model and in-person based initially.

Reflective Student Design Studio Comments[7]

The collaboration has helped me step out of my comfort zone and delve into the world of interdisciplinary design. I have learned to look at the project from another perspective other than structural and consider design aspects that I have never truly considered before. The advanced building systems Integration is beginning to make more sense to me as an engineer, which will be invaluable in an actual practice interdisciplinary workplace.

The high-rise interdisciplinary studio was a great experience of trying everything for the first time. I have learned a lot from all the activities we had as well as working on a project not only in an architectural environment but collaborating with a structural engineer. It showed both how challenging and rewarding this real process is.

Conclusions

The success of the Collaboratory is four-fold.

First is scale of this project, does require that no single discipline can design this building typology alone. All the architecture and engineering students did have a front row seat to understanding this as we all went through the design process, and they were able to apply these lessons in developing their own skyscraper projects.

Second, having the extended deadline of 20 weeks (as opposed to 10 weeks), allowed the collective design teams to dig into the technical weeds of this project and sort out the conflicting building system integration issues that in a large-scaled project like this requires. Students gained a great deal of insight into why this level of design development is important to understand, even in the academic design studio setting.

The third, the level of student's accountability was heightened in this academic environment, when working with professionals who do expect that the students have similar levels of accountability for their academic project work as they would expect from someone who is working in their office. The high caliber of professionally framed feedback that all of the students were exposed to was a motivating factor for embracing the high learning curve that was needed in developing a project at this scale.

Fourth and last, the authors enjoyed working together and is a primary reason they have co-taught a version (but never at the scale of a skyscraper before) of this studio for almost fifteen years. They admire each other's work, value each other's ideas, and respect each other's contributions. This chemistry has allowed them to freely share ideas with each other, but more importantly with students, design professionals, and colleagues and to take on what we would consider the most complicated academic / professional partner collaboration during this time period that we have worked together. We do have an interest in developing another collaboration at a similar scale in the future, given the lessons learned from this one.

Acknowledgements

We thank Skidmore Ownings and Merrill, San Francisco, California office for the extensive amount time devoted to preparation for this course along with the generous time devoted to course project reviews, lectures/workshops. Thank you for the hosting of the 33 students for our first field trip in their offices in San Francisco (pre pandemic), and providing the overview for skyscraper site, compelling introductory lecture on the importance of the skyscraper typology along with going through all warmup tower models for brick weight testing. During this 20-week course, it seemed at times, that SOM had devoted their entire office (in which the Chicago was added to provide the latest tall building's wind engineering research) to supporting this studio with the supply of an endless number of amazing critics who offered in depth architectural and structural insights to the range of team projects – which was an inspiration the students and of course paper authors.

Endnotes

1. Syllabus 2020, Advanced High-Rise Design Collaboratory, January 1, 2020, Cal Poly, SLO, CA: Fowler, Dong, SOM/SF: Chow, Sarkisian

2. *Alejandro Zaera-Polo, "High Rise Phylum 2007", Harvard Design Magazine, Spring/Summer 2007 (Cambridge, MA, Harvard University Graduate School of Design, 2007)*

3. Arup Journal, The Key Speech, Ove Arup and Partners, London, 1986

4. Donald Schon's work, Educating the Reflective Practitioner (1987)

5. Prologue Model (Weight Testing Models Assignment), By SOM's Chow/Sarkisian, January 1, 2020

6. Tobi Lütke of Shopify: Powering a Team With a 'Trust Battery'. NY Times, by Adam Bryant, April 22, 2016

7. Final Reflective Student Essay's, Advanced High-Rise Design Collaboratory, January – June 2020

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